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Comparison of Growth, Processing Yield, and Body Composition of USDA103 and Mississippi "Normal" Strains of Channel Catfish Fed Diets Containing Three Concentrations of Protein

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Abstract.—This study evaluated the effects of dietary protein concentration (26, 28, and 32%) on growth, feed efficiency, processing yield, and body composition of USDA103 and Mississippi "normal" (MN) strains of channel catfish raised in ponds. Fingerling channel catfish (average weight = 32.5 and 47.3 g/fish for USDA103 and MN strains, respectively) were stocked into 24 0.04-ha ponds (12 ponds/strain) at a density of 18,530 fish/ha. Fish were fed once daily to apparent satiation from May to October 1999. There were no interactions between fish strain and dietary protein concentration for any parameters measured. Regardless of dietary protein concentrations, the USDA103 strain consumed more feed and gained more weight than the MN strain. There were no differences in feed conversion ratio (FCR) or survival between the two strains. Feed consumption, weight gain, FCR, and survival were not affected by dietary protein concentration. The USDA103 strain exhibited a lower level of visceral fat, a higher carcass yield, a lower level of fillet moisture, and a higher level of fillet fat than the MN strain. Regardless of fish strains, fish fed the 32% protein diet had a lower level of visceral fat and a higher fillet yield than fish fed the 26% protein diet. Fish fed the 32% protein diet were also higher in carcass yield as compared to those fed the 28% protein diet. Fillet moisture, protein, and fat concentrations were not affected by dietary protein concentration. Results from this study indicate that the USDA103 strain of channel catfish appears to possess superior traits in growth characteristics compared with the MN strain that is currently cultured commercially. Both strains appear to have the same dietary protein requirement.

Fish raised under similar environmental conditions may grow at different rates because of differences in diet, feed allowance, feeding behavior, and fish strain. Different strains of fish may have different nutrient requirements, indicating a genotype-nutrition interaction that has been demonstrated in some fish including common carp *Cyprinus carpio* (Wohlfarth et al. 1983) and Nile tilapia *Oreochromis niloticus* (Romana-Eguia and Doyle 1992). However, this genotype-nutrition interaction has been shown to be insignificant for rainbow trout *Onchorhynchus mykiss* (Smith et al. 1988). Li et al. (1998) and Jackson et al. (2001) evaluated the possible interaction between channel catfish strain and dietary protein concentration under laboratory conditions with small fish and found that different strains of channel catfish (USDA102 and 103, Mississippi "normal", and Norris strains) appear to have a similar dietary protein requirement. However, potential genotype-nutrition interactions have not been examined extensively under pond culture conditions where fish are grown from fingerlings to harvestable size. Therefore, the present study was initiated to evaluate the effects of three dietary protein concentrations on production characteristics, processing yield, and body composition of channel catfish of the USDA103 and Mississippi "normal" (MN) strains raised in ponds under conditions similar to commercial catfish culture.

Materials and Methods

Channel catfish fingerlings of USDA103 (average weight: 32.5 g/fish) and MN (av-

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TABLE 1. *Ingredient and proximate composition of experimental diets (expressed as percentages on an as-fed basis).*

	Dietary protein (%)		
	26	28	32
Ingredient			
Soybean meal (48%)[a]	33.0	39.0	50.9
Wheat middlings	26.9	20.9	8.9
Dicalcium phosphate	0.44	0.45	0.46
Other ingredients[b]	39.7	39.7	39.7
DE/P ratio[c] (kcal/g)	10.8	10.2	9.2
Proximate Analysis			
Crude protein	27.7	29.0	32.2
Crude fat	5.2	6.1	5.5
Dry matter	89.7	88.9	87.7

[a] Values in parentheses represent percentage crude protein.

[b] Other ingredients include the following: meat, bone and blood meal (65% protein), 3%; corn grain, 35.0%; catfish offal oil, 1.5%; C-free vitamin premix, 0.1%; trace mineral premix, 0.1%; vitamin C supplied by L-ascorbyl-2-polyphosphate (25% activity), 0.03%. Vitamin and trace mineral premixes were the same as described by Robinson and Li (1996).

[c] DE/P ratio = digestible energy to crude protein ratio. DE was estimated based on tabular values of NRC (1993) and Robinson and Li (1996).

erage weight: 47.3 g/fish) strains were stocked into 24 0.04-ha ponds (12 ponds/strain) at a rate of 18,525 fish/ha. Four ponds were used for each strain × diet combination. Channel catfish of the USDA103 strain, a strain developed through family selection (Wolters 2000), were obtained from pond spawns at the Thad Cochran National Warmwater Aquaculture Center (NWAC), USDA Catfish Genetics Research Unit, Stoneville, Mississippi, USA. Fish of MN strain representing a commercial stock currently cultured in Mississippi were obtained from a commercial catfish farm in the Mississippi Delta.

Three diets containing 26, 28, or 32% crude protein were evaluated (Table 1). Each diet was formulated to meet all known nutritional requirements of channel catfish (NRC 1993) on a digestible basis. Digestible energy to crude protein (DE/P) ratios were 10.9, 10.2, and 9.0 kcal/g protein for the 26%, 28%, and 32% protein diets, respectively. The experimental diets were extruded floating pellets, and were manufactured in an experimental feed mill at the Delta Western Research Center (DWRC), Indianola, Mississippi, USA. Fresh lots of each diet were manufactured monthly. All dietary ingredients were obtained from the DWRC and were from commercial sources. Dry matter (oven drying), crude protein (combustion method), and crude fat (acid hydrolysis) of diet samples were determined using methods described by AOAC (2000).

Fish were fed the experimental diets once daily to apparent satiation from May to October 1999. Apparent satiation was achieved by allowing the fish to eat as much as they would consume within 20 min. Amounts of diet consumed by the fish in each pond were recorded daily to determine feed consumption per fish at the end of the study. During the growing season, water temperature and dissolved oxygen were monitored daily in early morning, mid-afternoon, and throughout the night using a YSI model 58 polarographic oxygen meter (Yellow Spring Instrument Company, Yellow Springs, Ohio, USA). Emergency aeration (provided by an electrical aerator) was used when dissolved oxygen levels dropped to 4 mg/L. Ammonia, nitrite, and pH were measured biweekly using a field kit (Hach Chemical Co., Ames, Iowa, USA). Water quality was maintained in ranges considered adequate for normal fish performance (Tucker and Robinson 1990). Dead fish were removed from ponds, weighed, and recorded for correction of feed conversion ratio at the end of the study.

At the end of the study, all fish were harvested, counted, and weighed. Thirty fish from each pond ranging from 570 to 900 g/fish were euthanized by a 40-volt electric pulse (Sylvesters, Inc., Louisville, Mississippi, USA). The fish were weighed individually, deheaded using a deheading machine (Barth Design, Buhl, Idaho, USA), eviscerated by hand, and visceral fat re-

moved and weighed. The skin was then removed mechanically (Mini-skinner, Collum Tool Co., Inc., Greenville, Mississippi, USA). Dressed carcasses were hand-filleted by two trained workers from a local processing plant to mimic commercial conditions. Each person filleted an equal number of fish from each pond to minimize person-to-person variation in fillet yield. Visceral fat and carcass and shank fillet yields were determined as percentages of whole body weight. Fillets (one fillet per fish, 10 fish per pond) were stored at −80 C for later proximate analyses. Individual fillet samples were separately ground into a paste using a food processor, and part of the ground fillet was lyophilized for 16 to 18 h prior to protein and fat analyses. Proximate analyses were conducted in duplicate on individual fillet samples. Crude protein (combustion method), crude fat (ether extraction), and moisture (oven drying) of fillet samples were determined using methods described by the AOAC (2000).

Data were subjected to an analysis of variance and a least significant difference procedure (Steel and Torrie 1980) using Statistical Analysis System version 8.0 software (SAS Institute, Inc., Cary, North Carolina, USA). Each pond was used as the experimental unit, and variation among ponds within a treatment was used as the experimental error in tests of significance. A significance level of 0.05 was used.

Results

Regardless of dietary protein concentrations, USDA103 strain channel catfish consumed more feed and gained more weight than MN strain channel catfish (Table 2). There were no differences in feed conversion ratio (FCR) or survival between the two strains. Feed consumption, weight gain, FCR, and survival were not affected by dietary protein concentration. The USDA103 strain had a lower level of visceral fat, a higher carcass yield, a lower level of fillet moisture, and a higher level of fillet fat than the MN strain (Table 3). Regardless of fish strains, fish fed the 32% protein diet had a lower level of visceral fat and a higher fillet yield than fish fed the 26% protein diet. Fish fed the 32% protein diet also had higher carcass yield than those fed the 28% protein diet. Fillet moisture, protein, and fat concentrations were not affected by dietary protein concentration. There were no interactions between fish strain and dietary protein concentration for any variable (Tables 2, 3).

Discussion

Results from the present study demonstrate that under pond culture conditions USDA103 strain channel catfish had about an 8.3% improvement in weight gain over MN strain fish regardless of dietary protein level fed. This difference in growth might have been greater had both strains been of the same size at stocking; however, it is unlikely that this small difference would have changed the results dramatically. The growth data agree with results of Li et al. (1998) who found that the USDA103 strain gained more weight than the MN strain when raised in flow-through aquaria. Previous pond trials also showed that the USDA103 strain exhibited superior growth characteristics compared with other strains that have been evaluated (Wolters 2000). The faster growth of the USDA103 strain of channel catfish is apparently due to the higher feed intake of the fish, as was seen in the present study and in previous studies (Li et al. 1998; Silverstein et al. 1999; Jackson et al. 2001).

It is not clear whether the higher carcass yield of the USDA103 strain is due to genetics. It may be partially related to the lower level of visceral fat in this strain as compared with the MN strain. Unpublished data from NWAC indicate that carcass yield of channel catfish is inversely correlated to visceral fat level. Also, within a size range of 500 to 1,000 g, larger channel catfish tend to give a higher carcass yield than smaller fish (Bosworth et al., 2001). It is unlikely that the higher level of fillet fat in

TABLE 2. *Mean feed consumption, weight gain, feed conversion ratio (FCR), and survival of USDA103 and Mississippi "normal" (MN) strains of channel catfish fed diets containing three levels of dietary protein in ponds. Means represent average values of four ponds per treatment.*

Fish strain	Dietary protein (%)	Feed consumption (g/fish)	Weight gain[a] (g/fish)	FCR (feed/gain)	Survival (%)
Individual Treatment Means[b]					
USDA103	26	664	400	1.66	95.6
MN	26	596	356	1.67	96.3
USDA103	28	666	406	1.65	98.6
MN	28	582	382	1.53	92.0
USDA103	32	667	406	1.65	96.1
MN	32	615	381	1.61	96.4
Pooled SEM		21.9	12.1	0.04	2.0
Pooled Means for Fish Strain[c]					
USDA103		665 a	404 a	1.65	96.8
MN		598 b	373 b	1.60	94.9
Pooled Means for Dietary Protein[d]					
	26	630	378	1.67	96.0
	28	624	394	1.59	95.3
	32	641	393	1.63	96.3
ANOVA					
Fish strain		*[e]	*	NS	NS
Dietary protein		NS	NS	NS	NS
Fish strain × dietary protein		NS	NS	NS	NS

[a] Mean initial weight was 32.5 and 47.3 g/fish for USDA103 and MN strains, respectively.

[b] The LSD procedure was not conducted for individual treatment means because the interaction was not significant.

[c] Pooled means in each column followed by different letters were found to differ at the 0.05 significance level by the LSD procedure (Steel and Torrie 1980).

[d] The LSD procedure was not conducted because main effect was not significant.

[e] Significant ($P \leq 0.05$).

USDA103 strain fish in the present study was caused by genetics or fish size, but rather was a result of increased feed intake and faster growth exhibited by this strain. Even though USDA103 strain fish gained more weight than the MS strain fish, fish of similar size were collected from each pond for processing and proximate analysis.

No interactions between channel catfish strain and dietary protein concentration were observed for any variable in the present study. Both strains responded to dietary protein concentration in a similar manner, which suggests that the two strains have a similar dietary protein requirement. Previous laboratory studies comparing USDA102 and 103, Norris, and MN strains of channel catfish also indicated that these strains of channel catfish had a similar protein requirement at the fingerling stage (Li et al. 1998; Jackson et al. 2001). Smith et al. (1988) compared the growth of 10 rainbow trout strains fed diets formulated with either plant or animal protein and found that significant differences in growth rate were due to fish strain but not to dietary protein sources and the dietary protein × strain interaction. However, Wohlfarth et al. (1983) found that certain strains of common carp grew faster than other strains when fed different diets. A similar genotype-nutrition interaction has also been reported for Nile tilapia (Romana-Eguia and Doyle 1992). It should be noted that only two strains of

TABLE 3. *Mean visceral fat, carcass and fillet yields, and fillet composition of USDA103 and Mississippi "normal" (MN) strains of channel catfish fed diets containing three levels of dietary protein in ponds.*

Fish strain	Dietary protein (%)	Visceral fat[a] (%)	Carcass yield[a] (%)	Fillet yield[a] (%)	Fillet moisture[b] (%)	Fillet protein[b] (%)	Fillet fat[b] (%)
Individual Treatment Means[c]							
USDA103	26	2.95	61.9	36.0	73.0	18.4	7.1
MN	26	3.44	60.3	36.1	74.2	18.2	6.9
USDA103	28	2.59	62.4	36.4	72.9	18.1	7.8
MN	28	3.41	60.7	36.1	73.6	18.7	6.4
USDA103	32	2.46	63.5	37.3	73.0	17.8	8.0
MN	32	3.18	60.9	36.5	74.5	18.0	6.1
Pooled SEM		0.11	0.41	0.32	0.61	0.53	0.55
Pooled Means for Fish Strain[d]							
USDA103		2.67 b	62.6 a	36.5	73.0 b	18.1	7.6 a
MN		3.34 a	60.6 b	36.2	74.1 a	18.3	6.5 b
Pooled Means for Dietary Protein[d]							
	26	3.19 x	61.1 x	36.1 x	73.6	18.3	7.0
	28	3.00 xy	61.5 x	36.2 xy	73.3	18.4	7.1
	32	2.82 y	62.2 y	36.9 y	73.8	17.9	7.1
ANOVA							
Fish strain		*[e]	*	NS	*	NS	*
Dietary protein		*	*	*	NS	NS	NS
Fish strain × dietary protein		NS	NS	NS	NS	NS	NS

[a] Means represent average values of 30 fish from each of four ponds per treatment.

[b] Means represent average values of 10 fish from each of four ponds per treatment.

[c] The LSD procedure was not conducted for individual treatment means because the interaction was not significant.

[d] The LSD procedure was conducted only for variables with a significant main effect. Pooled means in each column followed by different letters were found to differ at the 0.05 significance level by the LSD procedure (Steel and Torrie 1980).

[e] Significant ($P \leq 0.05$).

channel catfish and three dietary protein levels were evaluated in the present study, and that the lack of strain-dietary protein interactions does not necessarily imply that interactions do not exist between channel catfish strains and other dietary nutrients.

Effects of dietary protein concentration on production characteristics, processing yield, and body composition of pond-raised channel catfish in this study were similar to our previous reports (Robinson and Li 1997, 1999; Li et al. 2000). These studies generally demonstrated that a dietary protein level of 24% to 26% is adequate for maximum growth of pond-raised channel catfish when fed to satiety, and that a minimum dietary protein level of 28% is required for maximum growth and processing yield as well as acceptable fillet fat levels. However, in the present study, dietary protein concentrations in the range of 26% to 32% did not affect fillet composition. The apparent differences between fish fed the various dietary levels of protein in the present study were that fish fed the 32% protein diet had a higher carcass yield than fish fed the lower protein diets (26% and 28%) and that the 26% protein diet resulted in a higher level visceral fat and a lower fillet yield than the 32% protein diet, regardless of fish strain. This could have been caused by the higher DE/P ratio in these lower protein diets. However, our previous studies using similar processing methods did not

show a significant difference in carcass yield between fish fed 28% and 32% protein diets (Li et al. 2000) or among fish fed 26, 28, or 32% protein diets (Li et al., in press) with essentially the same DE/P ratios as the present study.

Given the faster growth of the USDA103 strain, raising this strain could result in considerable economic advantage to the producer. However, because of the nature of the catfish industry, this advantage may not be realized and the economics will vary greatly within and among years. For example, the price of catfish ranged from about $1.28 to $1.76/kg in 2001. At low fish prices, the producer is unlikely to be able to pay a premium for faster growing fingerlings. Another issue is that harvest dates are based on factors other than having harvestable size fish including market needs, off flavors, etc. Thus the advantage of being able to grow a fish to harvestable size quicker may be lost due to constraints that are not related to the biology of the fish. The bottom line is that it is difficult to assign a set economic value to the USDA103 strain. Given the best scenario of high fish prices, low feed prices, and timely markets, the economic gain could be significant.

In summary, the USDA103 strain of channel catfish appears to possess superior growth traits compared with the MN strain that is currently cultured commercially. Both strains have a similar dietary protein requirement because they respond to dietary protein concentration and composition in a similar manner. Based on results from the present and previous studies and considering growth, feed efficiency, processing yield, and body composition data, a 28% protein diet appears to be an economic choice for channel catfish grow-out.

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